(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
28 December 2000 (28.12.2000)

PCT

(10) International Publication Number
WO 00/78510 A2

(51) International Patent Classification[7]: B25D

(21) International Application Number: PCT/IB00/00812

(22) International Filing Date: 19 June 2000 (19.06.2000)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
BA99A000024 22 June 1999 (22.06.1999) IT

(71) Applicant: PRIVER INDUSTRIALE S.R.L. [IT/IT]; Via Per Faggiano - I Traversa, I-74100 S. Giorgio Jonico (IT).

(72) Inventor: GALLO, Pasquale; Viale Unità d'Italia, n. 101, I-74100 Taranto (IT).

(74) Agent: LAFORGIA, Domenico; Via Garruba, 3, I-70122 Bari (IT).

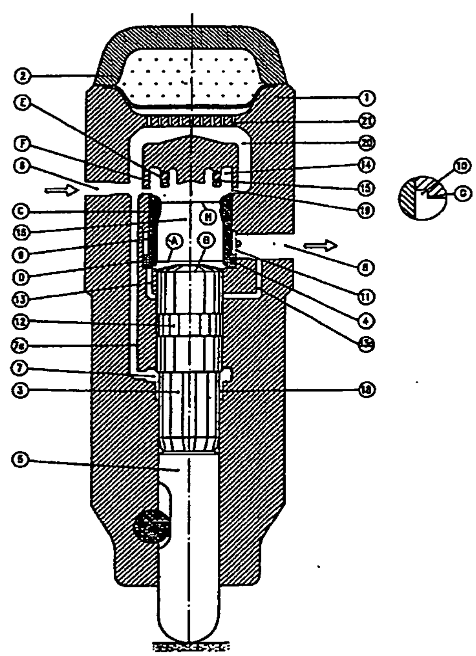
(81) Designated States *(national)*: CZ, HU, PL, SK, TR.

(84) Designated States *(regional)*: European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE).

Published:
— *Without international search report and to be republished upon receipt of that report.*

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

(54) Title: INNOVATIVE OIL-DYNAMIC PERCUSSION MACHINE WORKING AT CONSTANT HYDRAULIC PRESSURE



(57) Abstract: Oil-dynamic percussion machine having a body (1) in which there are a piston (3) which transforms the hydraulic power of the feeding circuit in mechanical power, a tool (5) that transfers the mechanical power to produce the demolition work, a Nitrogen-filled high pressure hydraulic accumulator (2) having the function of storing the hydraulic power supplied by the feeding circuit and characterised by a modulator slide valve (4) that keeps the operating pressure at a constant value; this mechanism controls the motion of the piston, his active displacement and the oil inlet and discharge control ports (19, 11).

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Title: **Innovative oil-dynamic percussion machine working at constant hydraulic pressure**

Applicant: **Priver Industriale Srl**

Technical field

The object of the present invention is an oil-dynamic percussion machine whose basic characteristic is the absence of any hydraulic regulating device, check or setting valves.

Most of the alternative percussion oil-dynamic machines known at the state of the art, work with the same basic principle: a piston, operated by high pressure not-compressible fluid, is accellerated into high speed and has an impact on the tool producing the demolition. The impact energy, under the form of pressure energy, is stored in a nitrogen charged (or other equivalent gas). The high pressure in the backhead is directly connected with the high pressure circuit acting on the middle area of the piston helping the piston upstroke.

Other mechanisms connect alternatively high and low pressure circuits with the piston head. In these mechanisms the piston is moved alternatively in the extreme positions, called top dead point and bottom dead point. The impact energy is directly proportional to the piston stroke and to the sum of the dynamical forces acting on it.

It is, therefore, to keep the oil pressure in the backhead at a

constant value of the oil-dynamic pressure in the accumulator, as the value of the impact energy depends on it. Special valves, controlled by the accumulator's pressure, regulate the discharge port to vary, as consequence, the pressure drop between the dynamic pressure that is determined on the head of the piston and the pressure of the return circuit. This means that the value of the dynamic pressure in the accumulator is inversely proportional to the lifting speed of the piston.

A valve of this type is described in the European Patent No. 0085279 and is total part of the apparatus disclosed in the US Patent No. 4.380.901.

The detriment with these applications is the regulation of the pressure control valve. This is a strongly unstable element due to very short time constants and to the difference between its control characteristic and that referred to the operating conditions.

This instability results in high pressure peaks on the head of the piston that produce vibrations and bouncing of the percussion machine. It is therefore necessary to regulate the hydraulic system of the operating machine or that of the control valves, specially during the installation. As a consequence, an unproper regulation leads to damage of the machine's structure due to high mechanical stress or excessively powerful strokes, reducing considerably the life of like pumps, piping, distributors and so on. Lastly one more drawback is the hydraulic seal, that usually affect the machine/circuit system during working conditions, for any type of

lamination which implies thermal stresses that reduce the circuit reliability and performances. This dynamical seal could be realised only by using special type of materials.

Disclosure of the invention

The present invention solves the technical problems mentioned as it is characterised in that the percussion machine has no external control element and, consequently, no high pressure dynamical seal . The advantage is that the top dead point of the piston can be varied automatically, without any check, regulating or control apparatus, and thus to modulate in real time the active displacement of the pushing chamber and the impact energy on the tool of the hydraulic apparatus; all is done with the use of the oil-dynamic auto control of an element called modulator. In this way, the pressure value in the oil—gas accumulator is kept constant. That is the working pressure and, therefore, the active force on the piston are maintained constant improving the reliability of the percussion system, and also of the body frame and of the hydraulic operating circuit.

It is necessary to point out the difference between the innovative modulator of the present finding and a normal and known slide valve. Generally speaking, both pneumatic and hydraulic devices comprise a distributor or slide valve to provide the pressure. This distributor or slide valve has an ON-OFF control and is moved by the fluid to the extreme positions. A similar device is presented in

patents No. 368/15 and No. 0085279 in which is mentioned that it is part of the system that limits the upward stroke of the distributor by anticipating the phase of starting the piston off with respect to the top dead point . These devices are combined with "others that allow the exhaust of the compressed fluid at different speeds from the protrusion of the distributor, in the 2 C annular chamber that this same protrusion forms in the upper part of groove 2". A similar device is described in U.S. Patent No. 4.380.901 with a valve connected to the high pressure line, that determines the motion law. In the device disclosed in the French Patent No. 8114043 a one-way valve produces the alternative moving of the piston. Therefore, from literature and from the state of the art, it is evident that neither the distributor's stroke, nor its speed can be regulated without external device or other means. With the hydraulic slide modulator of the present invention, the outlet ports opening of the hydraulic circuit is automatically controlled by the position of the modulator. This is an innovative evolution of the traditional spool-type distributor.

Another aim of the invention is the easy installation in service due to the absence of setting procedures and checking of the flowrates and working pressure. Therefore the invention solves the specific problem of rental of the hammers where daily servicing and maintenance are difficult tasks, as the oil-dynamic percussion apparatus can be used on different machines and circuits according to the needs.

These and other advantages will be more closely discussed in the detailed description of the invention, referring to tables 1/7, 2/7, 3/7, 4/7, 5/7, 6/7 and 7/7 which display some feasible schemes as not restricted examples and how the invention works.

Way of carrying out the invention

With reference to the above mentioned tables:

- drawing. No. 1 displays the invention in a vertical cross-sectional view;
- drawing No. 2 and No.3 show the same scheme in 2 different operating positions;
- drawing No. 4 shows an enlarged detail of the head of the piston and of internal basis of the modulator;
- drawings No. 5 and No. 6 show the geometry and consequent regulation characteristic of the lower and upper discharge ports;
- drawing No. 7 displays a detail of the internal protection system;
- drawing No. 8 and No. 9 represent possible variations in the geometry of the piston.

With reference to drawing No. 1, the oil-dynamic percussion machine, according to the invention, comprises the following principal components: the body 1, a Nitrogen-filled high pressure hydraulic accumulator 2, a piston 3, a modulator slide type valve 4, a tool 5, a high pressure feeding line 6, the upward lifting volume 7 with the upward lifting volume line 7a, the low pressure

discharge line 8, the low pressure volume modulator 9, a hydraulic shock absorber modulator 10, push volume control - ports 11, the connecting annulus volume 12, the modulator lower discharge line 13 and the modulator lower discharge line 13a, the volume lifting modulator 14, control ports of the volume modulator 15, the push volume 16, the piston hydraulic shock absorber 18, high pressure outlet ports 19, the accumulator feeding line 20, accumulator passage ports 21, the over-flow valve 22, shown in drawing No. 7, a pre-opening zone of the piston A, a pre-opening zone of the modulator slide valve 3, the "meatus" of upper dynamic sealing of the modulator C, the "meatus" of lower dynamic sealing of the modulator D, the upper dynamic sealing of the body E, the internal dynamic sealing of the body F, the hydraulic "meatus" of the shock absorber G, internal calibrated zone of the modulator H.

The invention comprises an essential component: a two-chamber accumulator, fitted with pressurised oil and Nitrogen gas separated by a rubber diaphragm, which keeps Nitrogen. The oil-filled chamber is connected to the high pressure line of the hydraulic circuit and to the central part of the piston, to push the piston upward. The oil-filled chamber is also connected to the pushing chamber, where the modulator slide valve supplies pressurised oil.

The pressure in the oil chamber depends on the ratio of the inlet flowrate and the impulsive outlet flowrate. The discharge flowrate

is function of following parameters:

a) the upward speed of the piston that determines the oil discharge time through the discharge circuit as function of the pressure drop that has taken place. The outlet ports are automatically controlled by the top dead centre of the modulator slide valve that modulates the opening;

b) variation of the upward stroke of the piston, that defines the oil quantity of the passive cycle or return;

c) variation of the stroke of the modulator slide valve that determines in sequence the position of the top dead point of the piston and also of its stroke;

d) pressure peaks in the pushing chamber due to the return impact waves from the piston. The invention eliminates these pressure peaks by opening the outlet port before the impact;

e) characteristics of the hydraulic slowing down during the last portion of the upward motion of the modulator;

f) complete duration of a active/passive working cycle.

The modulator valve interacts with the piston determining automatically the sequential control of the above parameters.

Example

With reference to drawing No.1, the modulator spool valve 4 is in idle position, and the piston 3, is at bottom dead centre. The lower discharge line of the modulator 13 and 13a is closed. From the high pressure feeding circuit line 6, the oil flows in the upward

push volume 7 through circuit 7a, and in the pushing chamber 16 through the high pressure oil inlet port 9. The oil will push the Nitrogen in the high pressure oil-gas accumulator 2, in the secondary feeding circuit 20 through the ports 21. The hydraulic seal of the high pressure towards the low pressure is ensured by the coupling between the modulator and the body. Under this condition the high-pressure feeding acts on the piston head 3 and on the upward pushing volume 7. Considering the difference of the areas, the high pressure pushes the piston downwardly contrasted in the motion from the reaction of the tool.

At the same time, the feeding high pressure acts on the exposed surface of the modulator slide valve 4, that has a volume 9 connected to the low pressure circuit 8 through the ports of pushing volume 11 and the discharge circuit 8 of the modulator spool valve. The difference of the pushing areas together with the pressure differential of the static pressure between the feeding pressure and the discharge pressure, determine the upward force that lifts the modulator spool valve 4 upwardly at the maximum of the allowed stroke; in this way the closing of the inlet 19 and the opening of the pushing volume port 11 are obtained. At the end of its stroke, the modulator spool valve 4 is slowed down by an hydraulic absorber modulator 10 and the oil contained in the volume 14 is discharged through the port 15.

In this way the value of the static pressure in volume 16 is decreases allowing the upward force in the pushing volume 7, to

prevail, starting the upward motion of the piston 3 that provides to discharge the residual oil into volume 16 in the low pressure discharge circuit 8 through the control port 11.

In this phase, the high-pressure oil inlet port 19 is closed, and the oil from the inlet oil feeding high pressure circuit, fills the oil - gas accumulator 2 through the circuit line 20 and the ports 21 up to the dynamic pressure of the feeding circuit.

The piston 3 free to rise (Fig. 2), enters the modulator spool valve 4 and presses against the rising volume of the modulator slide valve 14 through the ports 15 determining a downward force of the modulator 4 which pushes the piston downwardly, being the lower discharge circuit of the modulator 13, 13a, open.

The dynamic interaction between the reciprocate motion of the piston 3 and the opposite motion of the modulator slide valve 4 ends when the modulator slide valve opens the high pressure oil inlet port 19 (reaching the extreme leaning position) and when closing the port 11 it recreates the dynamic "meatus" seal D. From the high pressure feeding circuit 6 the oil enters both the pushing volume 16 and the upward pushing volume 7 thanks to the volume of the oil compressed by the Nitrogen contained in the accumulator 2. Therefore, the same pressure value acts both on the upper part of the piston 3 and on the lower part of the volume 7 generating a downward force proportional to the difference of the two areas. The resulting force is equal to a sudden downward push that acts on the piston 3 giving it a

uniform acceleration motion.

When the area A of the piston 3 reaches the position B of the modulator spool valve 4 earlier than it should (with respect to the impact position on the tool, which has previously closed the circuit 13, 13a), it eliminates the dynamic "meatus" A/B and allows the high pressure active oil to completely pressurise the modulator spool valve 4 that presents a volume 9 at low pressure. The low pressure volume 9 of the modulator slide valve 4 multiplied by the difference in pressure between that established in the accumulator 2 and that in the discharge, pre-existing in the volume 9, determines a force proportional to the dynamic pressure generated in the volume 16. This force launches the modulator upward closing the high-pressure oil inlet port 19 in the direction of the modulator upward volume control 14.

The modulator slide valve 4 transforms the kinetic energy by entering at high speed the upward modulator control volume 14, creating a dynamic "meatus" E, F, putting into pressure the modulator control volume 14 and, by partially opening the pushing volume ports 11, forces the oil (trapped in the volume 14) to flow through the ports 15, having exponential type regulating characteristics.

If the dynamic pressure in the volume 16 is very high, being the oil in the volume 14 completely discharged, the modulator slide valve 4 will stop at the top dead centre. On the contrary, if the dynamic pressure generated is very low, the modulator slide valve

4 will end its stroke as it enters the volume 14 and begins to pressurise it. Likewise, when the modulator slide valve 4 is more charged, it will open a higher portion of the pushing volume control port 11 determining a minor hydraulic resistance to discharge; the piston 3 will speed up thanks to a minor pressure difference in discharging the disenergised oil through the lower pushing volume ports 11. Therefore, reducing the discharge time, the pressure in the accumulator 2 tends to decrease.

The piston 3 impacts with the tool 5 and goes up at a speed that is function of the difference between the upwards push, and that of the discharge pressure existing in the chamber 16 multiplied the pushing area of the piston 3. During the upward stroke the piston enters the modulator slide valve 4 at its variable top dead centre, pressurising its upper part in the volume 14. The lower part of the piston is connected with the open discharge circuit 12, 13, 13a, it goes down opening the ports 19 and re-establishing the operating cycle. This allows to constantly maintain the medium values of the pre-established operating pressure.

The degree of accuracy for the definition of the geometry of the fluid-dynamic passage to optimise the fine tuning and the timing of the modulator slide valve 4 is very important. The aim is not to have areas at different speeds: the consequent pressure variations can influence the time constant of the modulation system. Therefore, the path that the oil must carry out through the annulus port and then in the defined pushing volume 16 must be optimised.

The inverse-cone shaped head of the piston 3 forms an inlet passage with the internal curve and conical base of the modulator slide valve 4 (Fig.4). The aim of this special geometry is that of transforming in real time the fluid's kinetic energy into an instant pressure energy that moves instantly the modulator slide valve 4. Afterwards the fluid passes through the volume control ports 11 modulating the stall position of the modulator. These ports 11 can be of different shape as described in Fig. 5: circular section, rectangular or trapezoidal shape according to the law to be used. Likewise the discharge ports 15 (Fig.6), that define the variable position of the top dead centre of the modulator slide valve (4), have different shape. Generally speaking the ports have a regulating characteristic of exponential type as a function of the lift. For short strokes linear type regulations (settings) can be used with a considerable simplification of design and a minor accuracy of the control position of the top dead centre of the modulator.

The percussion machine according to another favorable embodiment is characterised in that the machine has a hydraulic absorber 10 that protects from mechanical stress the modulator slide valve 4. It prevents the modulator slide valve 4 to strike against accidentally. After the modulator slide valve 4 has risen to its top position, the volume 10, formed between the max. top dead centre of modulator 4 and "meatus" C and G, allows the transformation of the inertial energy of the modulator into thermal

one.

The percussion machine according to another embodiment is characterised in that the machine has an internal protection system (Fig.7), to maintain the level of the internal operating pressure and, as a consequence, of the impact energy of the piston against the tool within the mechanical stress predicted in the design phase.

The internal protection system will be activated in case of anomalous functioning of the hydraulic circuit that implies problems with excessive flow or unexpected fluctuations.

As already described, the regulating law of the volume control ports 14 towards volume 16 has a regulating characteristic of exponential type, therefore, the constant time should be reduced so that and the modulator slide valve 4 will obtain the maximum lift in the least possible time, favouring the operating condition at maximum displacement (maximum consumption of process oil). For this reason, the modulator slide valve lifting control volume 14 has been provided with a second circuit with ON-OFF type regulations which can operate in this extreme case. This second circuit has a simple BY-PASS directly connected with the accumulator and a non return valve 22 that has the function of priority as previously described and shown in Fig. 7.

Lastly, two important aspects should be pointed out for the correct sizing of the invention: the first is that the impact efficiency increases with the increase of the impact speed, and

the second is that the impact speed, being the acceleration constant on the piston, tends to increase with the increase of piston stroke. It is also known that the impact energy is proportional to the square of the impact speed, therefore, in design phase, to keep in due consideration what has been evidenced, the values of the piston stroke have to be kept within certain pre-established criteria's.

The consequence of this is that the push active diameter of the piston (DV16) on which the high pressure acts directly needs to be reduced proportionally.

The percussion machine can be modified according to different models or sizes maintaining however the same operating principle. Figs. 8 and 9 show 2 variations of the piston geometry 3 in which the active push diameter is reduced.

Claims

1) Oil-dynamic percussion machine having a body (1) in which there are a piston (3) which transforms the hydraulic power of the feeding circuit in out mechanical power, a tool (5) that transfers the mechanical power, channels (7a), (20), (6), control ports (19,(11),(15), control and pushing volumes (7) (16) that allow the process not compressible fluid, (e.g. oil) to transform the hydraulic power into mechanical one; including, also, a Nitrogen-filled high pressure hydraulic accumulator (2) having the function of storing the hydraulic power supplied by the feeding circuit (6) and to return it to the piston (3); this machine being characterised in that it comprises a modulator slide valve (4) that keeps the operating pressure at a constant value; this mechanism controls the motion of the piston, his active displacement and the oil inlet and discharge control ports (19), (11).

2) Oil-dynamic percussion machine according to the claim 1, characterised by the fact that it needs neither flow regulating, relief pressure regulator valves to control the operating pressure and / or the active or passive displacement nor mechanical stops of the piston stroke.

3) Slide modulator valve (4) of an oil-dynamic percussion machine characterised by the fact that it is moved exclusively by the oil-dynamic and by the hydraulic interaction with the piston (3).

4) Slide modulator valve according to the previous claim, characterised by the fact that its geometry, its particular shape together with the positions of said inlet (15) and discharge ports (11) and with the pushing and control volumes (16) (14) are very important in varying the stroke of the piston (3), the active displacement and also to the operating frequency,.

5) Slide modulator valve according to the claim 3 or 4, characterised by the fact that it automatically controls its own position dissipating kinetic energy in the volume (14) and in the meatus (E) and (F). Said modulator slide valve characterised, also, by calibrated internal and external surfaces which, together with the calibrated parts of the body (1), create the meatus (E), (F).

6) Slide modulator valve, according to the one of the claims from 3 to 5, characterised by the fact that it can control all the operating parameters by means of them the pressure in the oil-gas accumulator (2) and the impact energy can be kept at constant value.

7) Oil-dynamic percussion machine according to the claim 1 or 2, characterised by the fact that the oil paths inside the machine optimise the sensitivity and the timing of the said slide valve modulator.

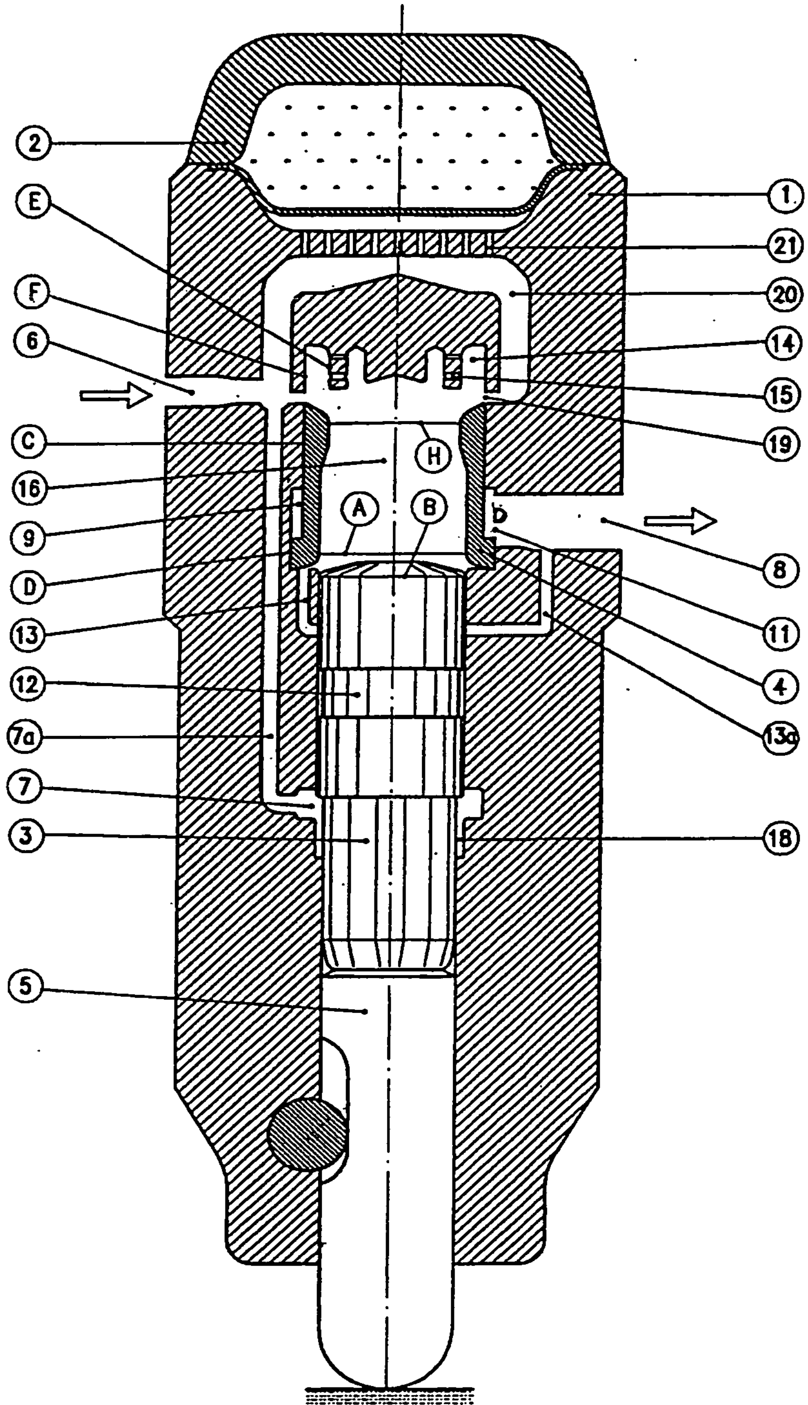
8) Oil-dynamic percussion machine according to the claims 1, 2 or 7, characterised in that the upper (15) and the lower (11) discharge ports are governed by particular regulating

characteristics.

9) Oil-dynamic percussion machine according to the claims 1, 2, 7 or 8 characterised in that it comprises a hydraulic shock absorber (10) which avoids (being the modulator slide valve in proximity of its top dead centre) the impact between the body (1) and the modulator slide valve (4).

10) Oil-dynamic percussion machine according to claims 1,2,7,8 or 9 characterised by a secondary BY-PASS (22) circuit that, in case of excessive and unexpected flowrates in the high pressure hydraulic feeding circuit, with its opening allow the system to reduce the pressure in the accumulator.

11) Oil-dynamic percussion machine according to the claims 1,2,7,8,9, or 10 characterised by the fact that the fast opening of the discharge ports (11) and the fast closing of the oil discharge ports (19) in the said volume (16) avoid any energy recovery and therefore any pressure peaks in the pushing volume (16).



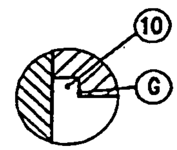


FIG. 1

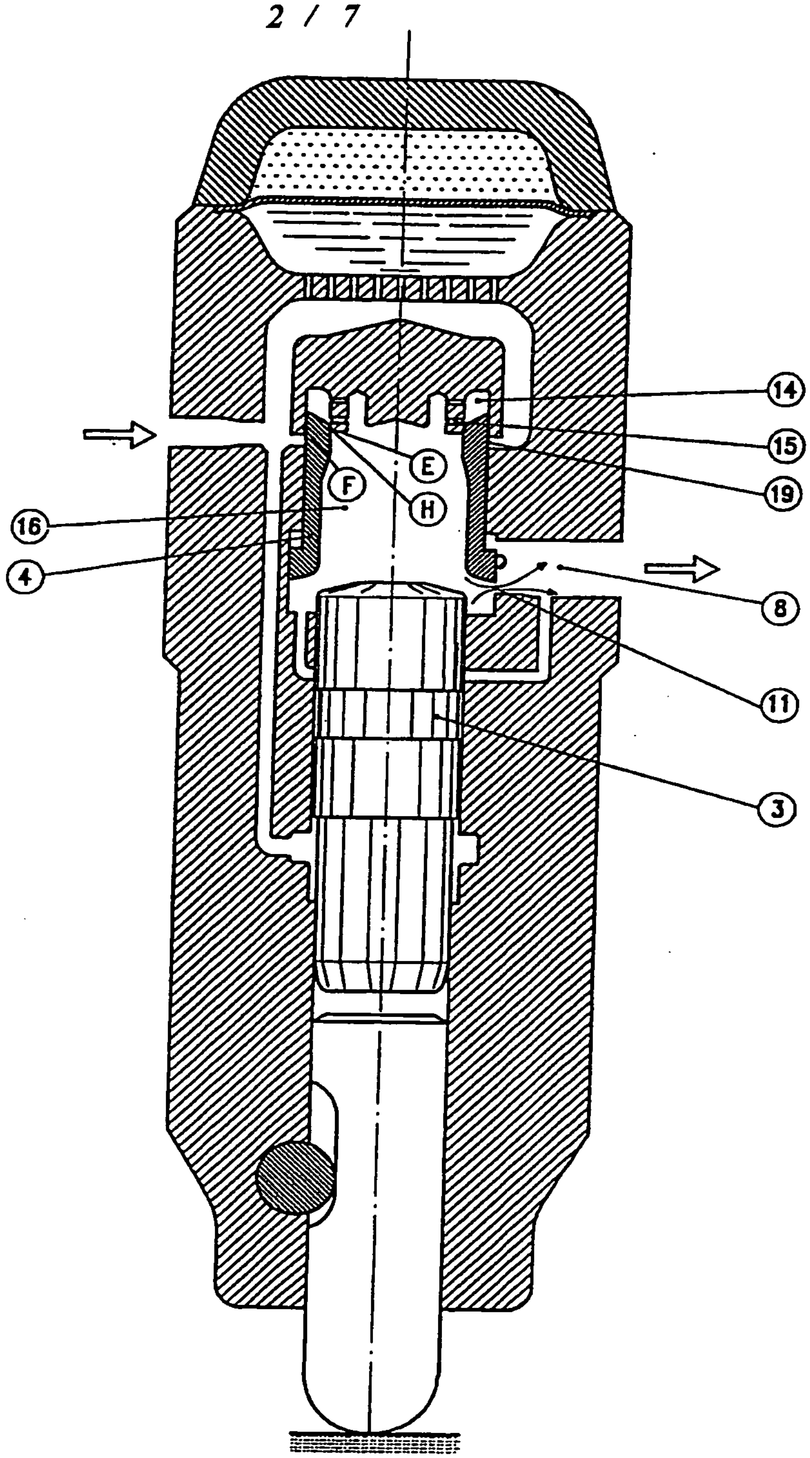


FIG. 2

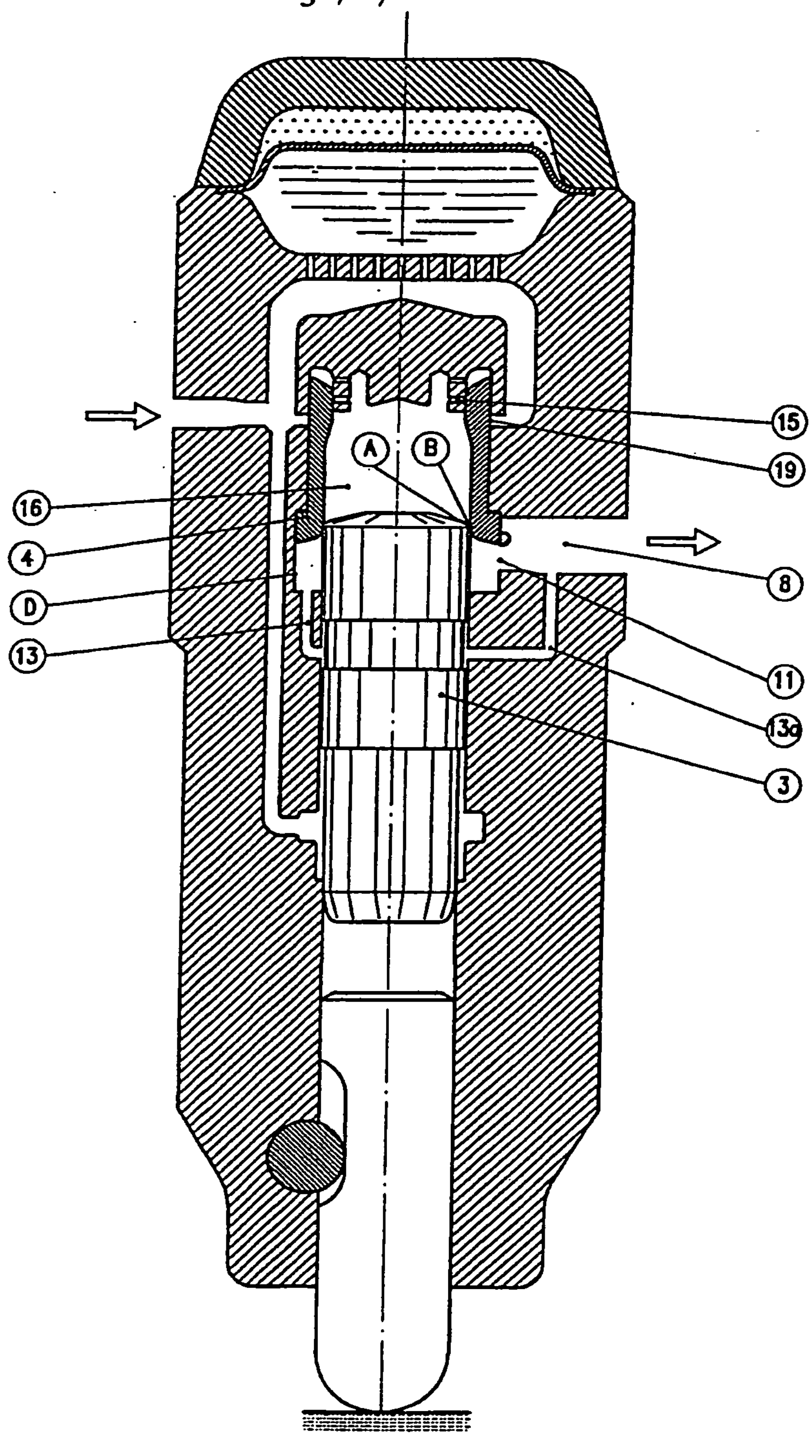


FIG. 3

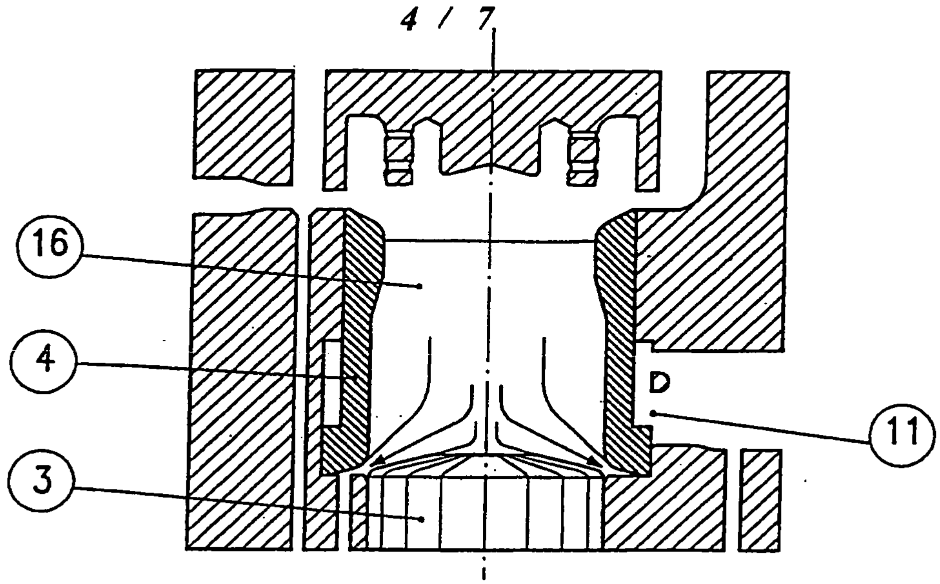


FIG. 4

REGULATING CHARACTERISTICS OF THE DISCHARGE PORTS 11

VOLUME 16

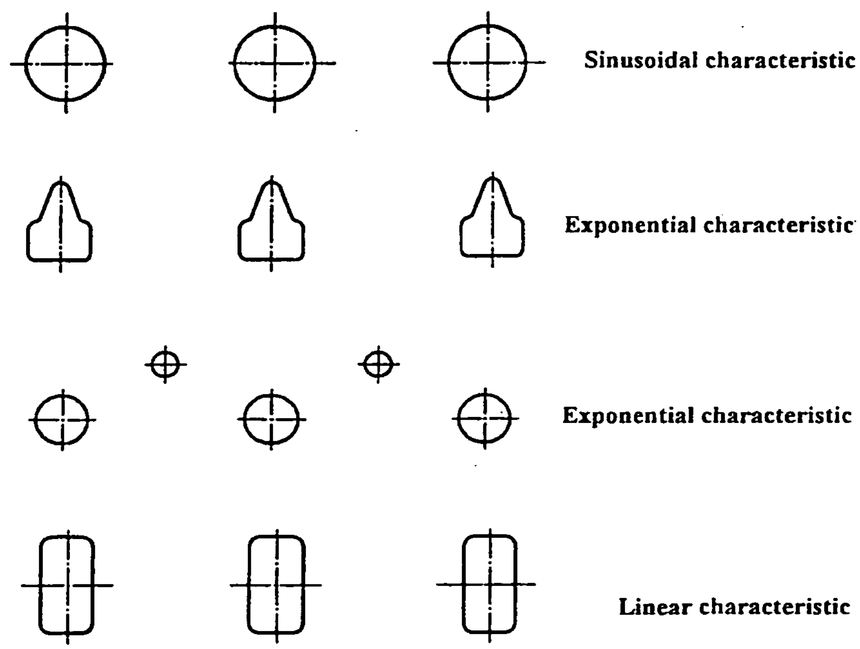
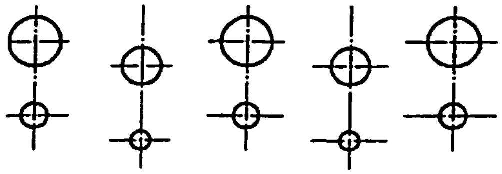


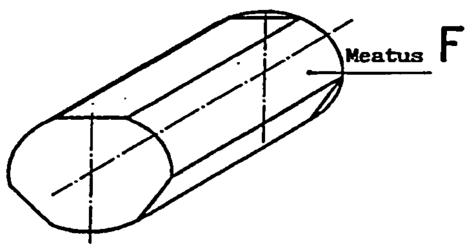
FIG. 5

REGULATING CHARACTERISTICS OF DISCHARGE PORTS 15

VOLUME 14



Exponential characteristic



Exponential characteristic

FIG. 6

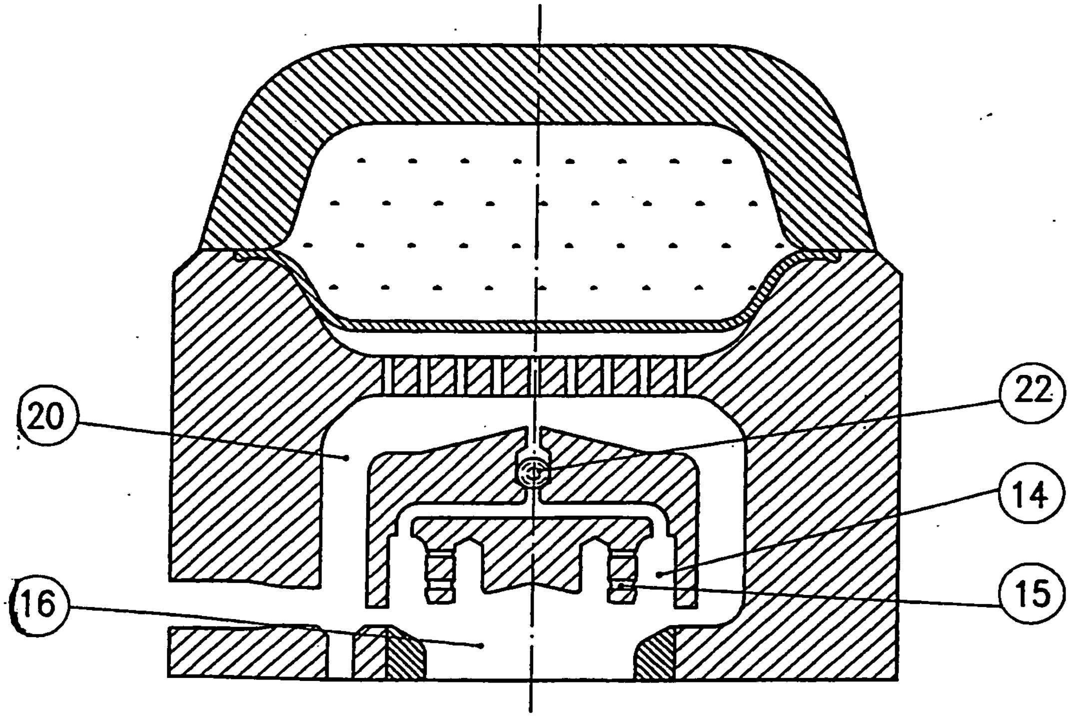


FIG. 7

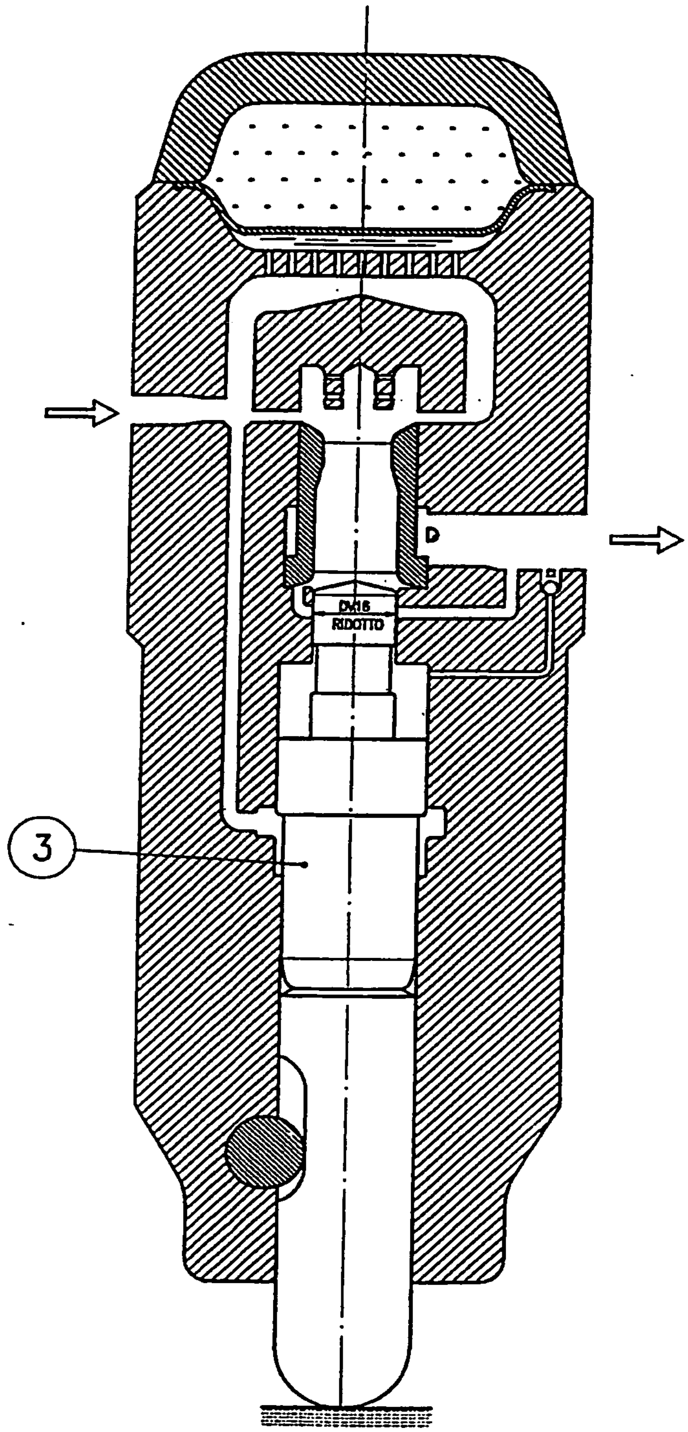


FIG. 8

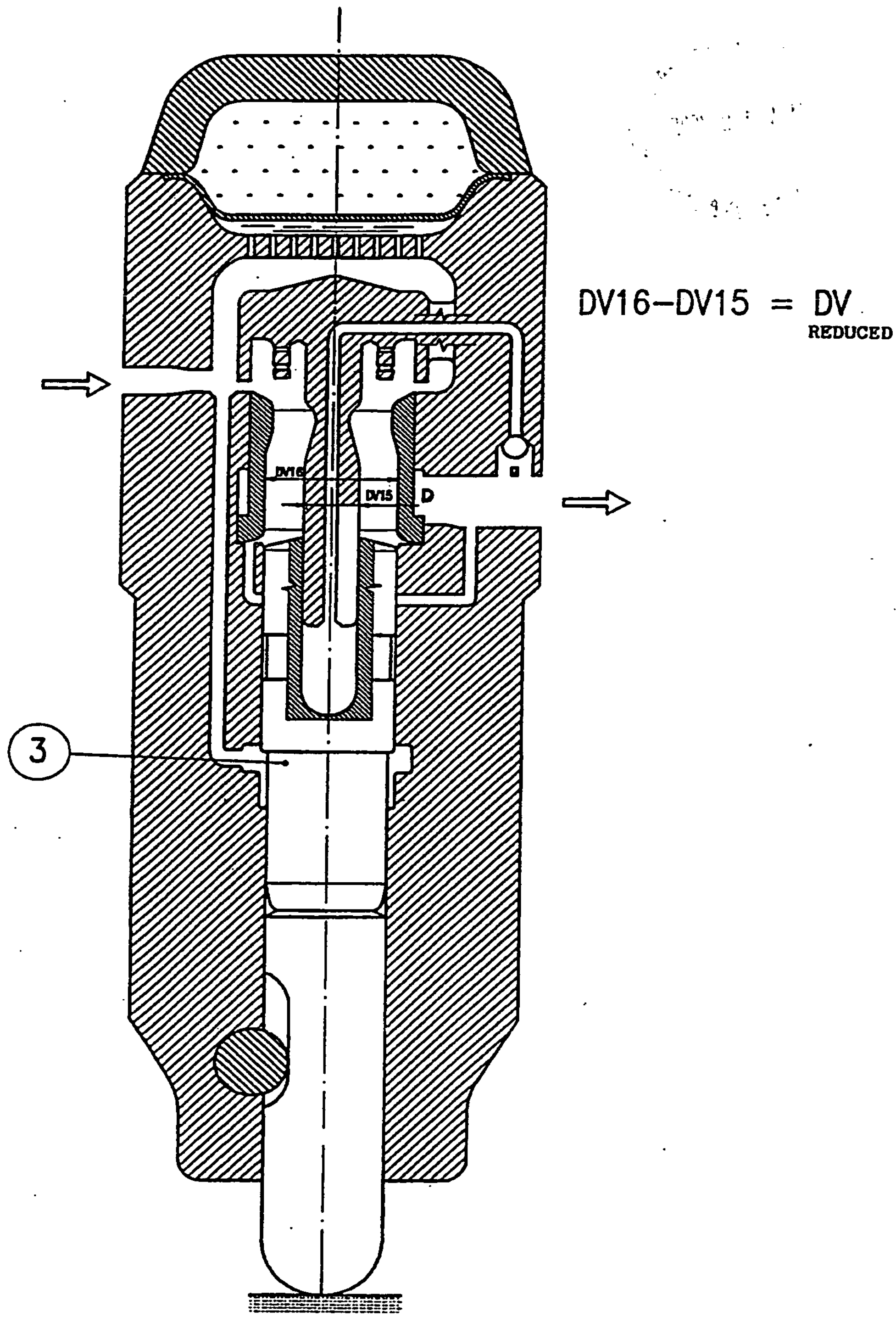


FIG. 9